(2)

SUSTAINABILITY

SURVIVABILITY

SUPPORTABILITY

TECHNICAL REPORT
NATICK/TR-91/002

AD

THE EFFECTS OF CHEMICAL PROTECTIVE GLOVES AND GLOVE LINERS ON MANUAL DEXTERITY

BY
RICHARD A. TEIXEIRA
CAROLYN K. BENSEL

DECEMBER 1990

FINAL REPORT
DECEMBER 1988-JANUARY 1990

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED

UNITED STATES ARMY NATICK
RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
NATICK, MASSACHUSETTS 01760-5000

SOLDIER SCIENCE DIRECTORATE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1 AGENCY USE ONLY (Leave blank)	2 REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December, 1990	Final; Dec. 88 - Jan. 90

4. TITLE AND SUBTITLE

The Effects of Chemical Protective Gloves and Glove Liners on Manual Dexterity

5. FUNDING NUMBERS

PE: 1L162723
PR: AH98
TA: CD
WU: 0Q00

6. AUTHOR(S)

Richard A. Teixeira and Carolyn K. Bensel

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Behavioral Sciences Division
Soldier Science Directorate
U.S. Army Natick Research, Development and Engineering Center
Natick, MA 01760-5020

8. PERFORMING ORGANIZATION REPORT NUMBER

NATICK/TR-91/002

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a DISTRIBUTION/AVAILABILITY STATEMENT

Approved for Public Release; Distribution is unlimited

12b. DISTRIBUTION CODE

13 ABSTRACT *(Maximum 200 words)*

This study was conducted to determine the effects on manual dexterity performance of two thicknesses of butyl, chemical protective gloves, 0.64 mm and 0.36 mm, and of two types of cotton glove liners, a seam-stitched and a string-knit version. Over seven working days, 12 male subjects performed three, fine-finger dexterity tests while bare-handed and while wearing each of the four glove and liner combinations. The subjects also completed a questionnaire designed to elicit their opinions of the handwear. Analyses of the subjects' times to test completion with the glove and liner combinations, expressed as a percentage of bare-hand times, failed to yield any significant interactions among the glove, the liner, and testing session variables. Also, the main effect of liner type did not reach significance, but the main effects of glove and of session did. The subjects' performance improved across sessions and was better when the 0.36-mm gloves were worn than when the 0.64-mm gloves were used. Although the subjects expressed a definite preference for the thinner butyl gloves, they did not consistently choose one cotton liner as being superior to the other. When forced to select the one liner that they preferred, 8 of 12 subjects chose the string-knit version.

14. SUBJECT TERMS

	PERFORMANCE (HUMAN)	TOXIC HAZARDS
GLOVE LINERS	MANUAL DEXTERITY	ARMY PERSONNEL
HANDWEAR	CHEMICAL PROTECTION	THICKNESS
INSERTS	BUTYL RUBBER	GLOVES

15. NUMBER OF PAGES 48

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20 LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

Table of Contents

Figures

Tables

Preface

This study was conducted by members of the Human Factors Branch, Behavioral Sciences Division, Soldier Science Directorate, U.S. Army Natick Research, Development and Engineering Center under the 6.2 program 1L162723AH98CD0Q00 -- Human Factors Analysis of Chemical Protective Clothing. The study was undertaken during December 1988 to January 1990.

The authors wish to thank Mr. Edward R. Hennessy, Natick, and Ms. Bonnie E. Patterson, GEO-CENTERS, INC., Newton Centre, Massachusetts, for their support in analyzing the data and the men of the U.S. Army Natick Research, Development and Engineering Center's Enlisted Volunteer Platoon who participated in this study.

The Effects hemical Protective Gloves and Glove L. 's on Manual Dexterity

Introduction

Five-finger gloves made of butyl rubber are worn by Army personnel to protect the skin from exposure to toxic chemicals. They are seamless and there is a smooth finish on the interior and the exterior surfaces (Department of the Army, 1986). The shape of the gloves, with a curved palm and the thumb in opposition to the index finger, mimics the shape of a relaxed hand.

Until recently, these gloves were produced in one thickness only, 0.64 mm (nominal). Soldiers have reported that the handwear interferes with performance of manual tasks because it is bulky and thick (Cox and Jeffers, 1981; Stack and Sager, 1988). These complaints have been substantiated by objective data. In a study by Bensel (1980), subjects performed five, timed, dexterity tests once a day for 14 consecutive weekdays with the bare hands and with the gloves. Over the last seven sessions, when the subjects were well-practiced and their performance was relatively stable, mean times to complete the tests with the gloves were between 13% and 55% longer than times with the bare hands.

Protective gloves were recently produced for use by Army personnel that are identical to the 0.64-mm gloves in all respects except that the newer handwear has a nominal thickness of 0.36 mm. Distribution of the thinner gloves to Army personnel is underway. In a study of the effects of various handwear thicknesses on manual capabilities, Bensel (1990) found that the 0.36-mm gloves resulted in faster times to complete both fine-finger and whole-hand dexterity tests than did the 0.64-mm gloves. Based on Bensel's study, it is expected that soldiers who wear the 0.36-mm gloves will be able to carry out manual tasks more efficiently than is possible with the thicker ones. In the future, the majority of soldiers will use the 0.64-mm gloves; Army personnel with duties that require a high degree of finger dexterity, such as those in medical occupations and those involved with keyboard operations, will be issued the thinner gloves.

When soldiers are given either thickness of butyl gloves, they are also given a pair of lightweight, seam-stitched, cotton gloves, which are commonly worn when handling film (Department of the Army, 1987). In their chemical protective application, the cotton gloves are to be worn as liners under the butyl to aid in

the absorption of moisture that accumulates within the impermeable rubber gloves. Just as the 0.64-mm butyl gloves have been a source of soldiers' complaints, so have the seam-stitched liners. It has been reported that they tear easily, are not long enough to cover the palm completely, and roll up during use, bunching across the fingers and the palm of the hand (Cox and Jeffers, 1981; Lee, Glumm, and Singapore, 1983).

Efforts are underway to identify more functional liners. One candidate being considered is a seamless, string-knit, cotton that is slightly thicker and more stretchable than the seam-stitched version. The two liners also differ in design and dimensions.

Branson, Abusamra, Hoener, and Rice (1988) studied the effects of the seam-stitched, the string-knit, and two other types of gloves on sweat rate, manual performance, and perceived comfort of the wearer. The gloves were worn as liners under the 0.36-mm butyl gloves. Subjects also wore another article of chemical protective attire used by Army personnel, an overgarment coat. Testing was conducted under ambient temperatures that ranged from 22.2 $^{\circ}$C to 29.7 $^{\circ}$C, with the mean being 26.1 $^{\circ}$C. Subjects participated in four, two-hour sessions, wearing a different liner throughout each session.

A session began and concluded with performance of one trial on each of five, timed, dexterity tests. Subjects were sedentary during the remainder of the session, completing a temperature perception and thermal comfort survey at 15-min intervals. A thermistor and a sweat capsule were taped to the nondominant hand and their outputs were recorded throughout the session. The liners were weighed immediately before they were donned to begin a session and immediately after they were removed at the end of a session to determine the amount of moisture retained.

With regard to perceived comfort of the liners, Branson et al. (1988) found that the seam-stitched were rated as being snugger than the string-knit, whereas the string-knit were rated as being the heavier of the two types. There was less of a weight change in the seam-stitched liners over the session than there was in the string-knit, but the difference was not significant. The effect of liner on sweat rate, hand skin temperature, and perceived hand skin temperature also failed to achieve significance. In addition, performance on the manual tests was not significantly affected by the type of liner worn.

Two issues related to chemical protective gloves and glove liners were not addressed in the study by Branson et al. (1988). One of these is the question of whether or not the liners differentially affect times to completion of manual tasks when

they are worn in conjunction with the 0.64-mm butyl gloves. It is possible that the string-knit liners, being somewhat thicker than the seam-stitched, will contribute further to the already-impaired dexterity capabilities associated with use of the 0.64-mm gloves (Bensel, 1980).

A second issue is related to the fact that wear of the Army's chemical protective, full-face mask in conjunction with chemical protective gloves has been found to extend times to complete some types of manual tasks beyond those recorded when only the gloves are worn (Bensel, Teixeira, and Kaplan, 1987; Waugh and Kilduff, 1984). The chemical protective mask was not used in the study conducted by Branson et al. (1988). Thus, there is no basis on which to determine whether or not differences occur between liners when manual tasks must be performed under the combined burden of protective handwear and a protective mask.

The Army's chemical protective ensemble consists of a mask, a mask hood, gloves, an overgarment, and overboots. When soldiers are outfitted in all these components, they are at risk to heat-induced illness even in temperate ambient environments because the materials used constrain the heat-dissipating mechanisms of the body, particularly sweat evaporation (Goldman, 1970; Tilley, Standerwick, and Long, 1987). To avoid heat casualties, work/rest cycles are instituted with rest periods increasing in frequency and in duration as ambient temperature and work rate increase (Department of the Army, 1977). Thus, the total time required to accomplish an activity is expanded in order to minimize the loss of personnel to heat illness. It has been reported that, even exclusive of rest breaks, more time is needed to complete an activity when outfitted in chemical protective clothing than when wearing regular uniforms (Cox and Jeffers, 1981; Stack and Sager, 1988).

Given this situation, it is critical that no protective clothing items be introduced for use by soldiers that contribute toward prolonging times to carry out military missions, and it is also critical that clothing items associated with improvements in performance efficiency be identified. Therefore, before a determination is made regarding whether the seam-stitched liners should be retained or replaced by the string-knit, their relative effects on dexterity capabilities when 0.64-mm gloves and a protective mask are being worn should be examined. This study was undertaken for the purpose of investigating these issues.

Method

Subjects

The participants were 12 Army men recruited from the Enlisted Volunteer Platoon at the U.S. Army Natick Research, Development and Engineering Center. Each man volunteered after being given an explanation of the nature and the purpose of the testing. The subjects ranged in age from 18 through 21 years and their mean age was 19 years.

Measurements of selected dimensions of the hand were taken on the subjects. Descriptions of the measuring techniques employed are presented in Appendix A and each subject's dimensions are presented in Appendix B.

Clothing

The two types of glove liners tested are pictured in Figure 1. It can be seen that the seam-stitched version does not have a wristlet, whereas the string-knit version does. In the case of both versions, the two members of a pair are identical and can be worn on either hand. Both liners are 100% cotton and made from a plain knit fabric. Additional information on the physical characteristics of the liners is presented in Table 1. The seam-stitched liners were available in two sizes and the string-knit were available in three.

Table 1. Physical Characteristics of the Glove Liners

	Liner	
Characteristic	Seam-Stitched	String-Knit
Fabric Weight (g/m^2)	135.6	352.7
Thickness (mm)	0.02	0.06
Yarn Number	18/1	14/1
Wales/mm	711.2	381.0
Courses/mm	660.0	432.0

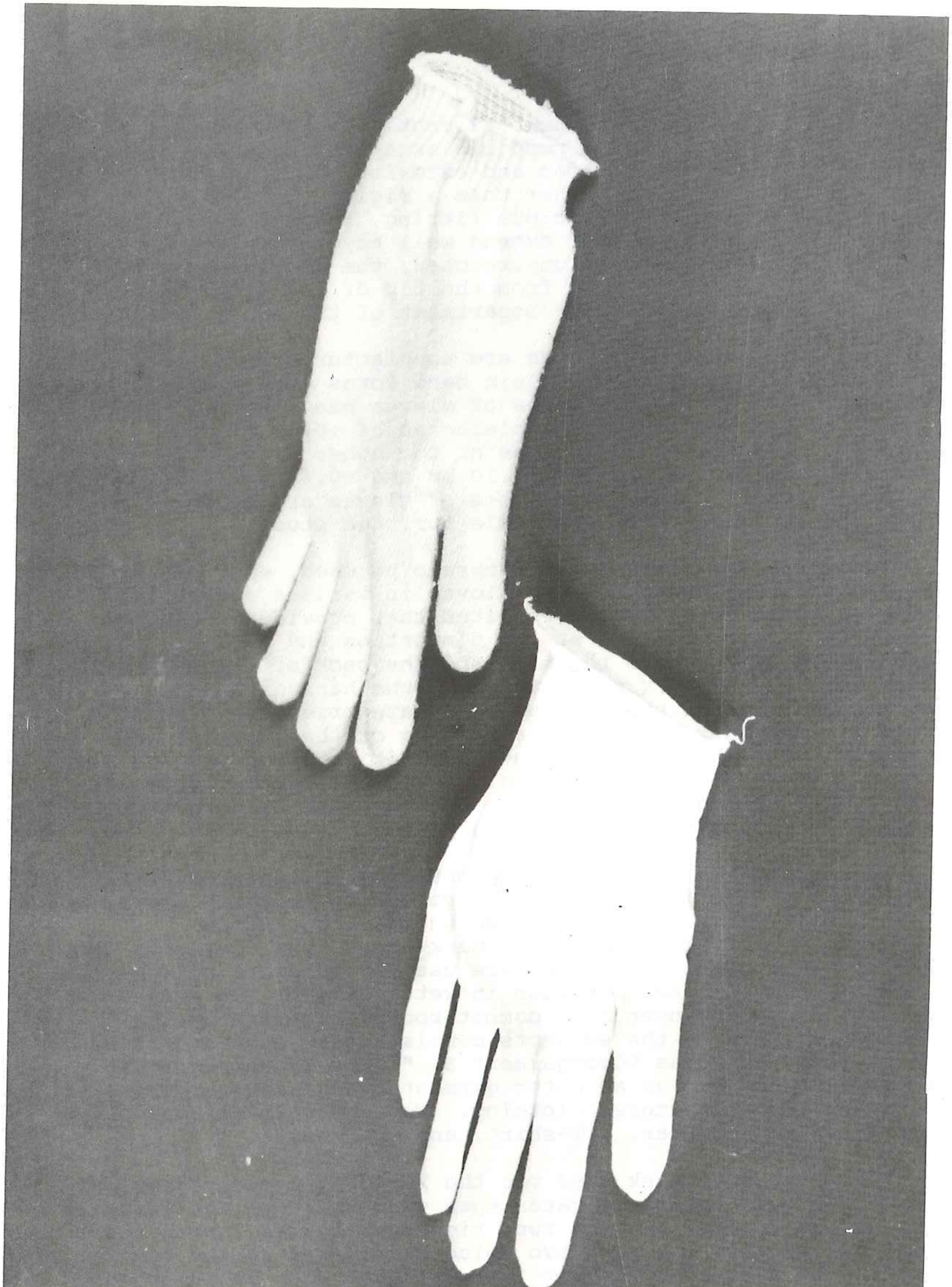

Figure 1. Seam-stitched (left) and string-knit (right) glove liners.

The two types of Army chemical protective gloves used in this study are identical in all respects except thickness. They have five fingers, smooth interior and exterior surfaces, and are in the shape of a relaxed, rather than a rigidly extended hand. The gloves were designed to be close fitting, but not "skintight." The gauntlets of the gloves extend well beyond the wrists (Figure 2). When flat and unstretched, the gloves measure between 35.6 cm and 36.8 cm from the tip of the middle finger to the edge of the rolled cuff (Department of the Army, 1986).

Both thicknesses of gloves are manufactured by a process that requires the dipping of porcelain hand forms into a butyl rubber solution. One of the two types of gloves has a nominal thickness of 0.64 mm and manufacturing tolerances of +0.18 mm and -0.13 mm. The nominal thickness of the other is 0.36 mm and the manufacturing tolerances are +0.10 mm and -0.05 mm (Department of the Army, 1986). Both thicknesses of gloves are produced in five sizes and all sizes were available for this study.

To select the sizes of handwear to be used, each man tried on the glove liners and the butyl gloves in various sizes until a size was found in each handwear item that provided a minimal amount of excess material at the fingertips and a tight, but not restricting, fit across the palm and the back of the hand. The sizes used and summary statistics for the hand dimensions of the men accommodated in the various size categories are presented in Table 2. Appendix B includes a listing of the sizes of the handwear items that provided the best fit for each subject along with a subject's hand dimensions. During the study, subjects were tested bare-handed and while wearing each thickness of butyl glove with each type of glove liner.

In addition to the chemical protective handwear, the other components of the Army's chemical protective clothing system were used in this study. These are overboots, a two-piece overgarment, a field mask, and a mask hood. The overboots are made of vinyl plastisol. They are used by soldiers not only in chemical environments, but also in wet weather. The subjects wore the overboots over Army combat boots. The particular overgarment worn by the subjects consists of a coat and trousers and is referred to as "Overgarment 84." The overgarment was designed to be worn as an outer garment over underwear alone or underwear and other torso clothing. The subjects in this study wore it over underwear, a T-shirt, and gym shorts.

The protective mask used was the XM-40-1, a preproduction model of a full-face respirator that was developed for issue to Army ground troops. It has two, rigid eye lenses, an outlet valve for expired air, and two voicemitters set in the face piece. The filtering element is a canister that is attached to

Figure 2. Butyl gloves.

Table 2. Mean Hand Dimensions of the Subjects (N = 12) as a Function of Glove and of Liner Sizes

	Hand Dimension				
Handwear Size	Hand Lgth.	Palm Lgth.	Thumb Crotch Ht.	Hand Circ.	Wrist Circ.
		0.64-mm/0.36-mm Butyl Gloves			
Small (n=3)	18.6	10.6	4.2	20.4	16.4
Medium (n=7)	19.2	10.9	4.4	21.4	17.1
Large (n=2)	19.2	11.2	4.2	22.5	18.1
		Seam-Stitched Liners			
Small (n=2)	18.3	10.4	4.2	20.2	16.0
Medium (n=10)	19.2	11.0	4.4	21.4	17.3
		String-Knit Liners			
Small (n=0)	--	--	--	--	--
Medium (n=10)	19.0	10.8	4.4	21.1	16.9
Large (n=2)	19.2	11.2	4.2	22.5	18.0

the face piece in the area of the left cheek. The mask hood has openings formed to fit around the lenses and the other elements set in the face piece. The hood extends over the wearer's head and neck and lies on the shoulders, the upper back, and the chest.

Testing Instruments

Three manual tests were included in this study. Two of them had been used in the glove liner study conducted by Branson et al. (1988). These were the O'Connor Finger Dexterity and the Purdue Pegboard Assembly Tests. The third was the Cord and

Cylinder Manipulation Test, which had also been used previously to measure aspects of manual dexterity and the effects of handwear on manual performance (Bensel, 1980; Bensel, 1990; Cattroll, 1983; McGinnis, Bensel, and Lockhart, 1973; McGinnis, Lockhart, and Bensel, 1972). The subjects were timed to the nearest 0.01 s on an electric, digital stop clock (Lafayette Instruments Model 54030) as they executed each test. Brief descriptions of the tests, which are listed below in the order in which they were performed, are as follows:

1. Cord and Cylinder Manipulation Test. The test was designed in this laboratory as a measure of proficiency in handling soft, flexible materials with the fingers. It is done with two hands and involves alternately stringing small cylinders on cord loops attached to a flexible base and intertwining the loops to form a chain with one cylinder mounted on each of 10 links.

2. O'Connor Finger Dexterity Test (Hines and O'Connor, 1926). This widely used test was reported by Fleishman (1954) to be a relatively pure measure of fine finger dexterity. It involves picking up three pins at a time and placing them in a hole using only the preferred hand. In this study, 20 holes had to be filled to complete the test.

3. Purdue Pegboard Assembly Test (Tiffin, 1979). Like the O'Connor Finger Dexterity Test, this test was found by Fleishman (1954) to be a measure of fine finger dexterity. However, Fleishman suggested that ambidexterity may also be a factor on the Purdue Pegboard Assembly Test because both hands must be used simultaneously. The test requires that assemblies consisting of a peg, a washer, a collar, and another washer be constructed through the coordinated actions of the two hands. In this study, 12 assemblies had to be constructed to complete the test.

In addition to employing the dexterity tests to obtain quantitative data, a questionnaire was developed to elicit subjects' opinions regarding the handwear being tested. The questionnaire, a copy of which is presented in Appendix C, was comprised of five sections. The first three, dealing with specific design characteristics and potential problem areas of the handwear that might have impaired performance on the dexterity tests, were completed four times during a test session. The next section, which required that the subjects rank the handwear with regard to the extent of the dexterity impairments experienced, was completed at the end of each of the seven sessions. The fifth and last section was administered only once, at the completion of a subject's participation in the

study, and was constructed to elicit opinions regarding the handwear preferred by the subjects.

Procedure

Before testing began, the subjects were fitted for the handwear and the other clothing items that they were to use during the study. The five hand dimension measurements were also taken (Appendices A and B). Pairs of subjects then participated in one, 2.5-h testing session per day for seven working days. During the first session, the subjects were familiarized with the three dexterity tests and the questionnaire and completed one practice trial on each test. For the practice period, each subject wore a T-shirt, gym shorts, combat boots, and a chemical protective overgarment and overboots; handwear and headwear were not used. After a 15-min rest break following the practice, the subject donned a chemical protective mask and mask hood, and formal testing began. The three dexterity tests were performed in the order listed above five times, once bare-handed and once under each combination of butyl gloves and glove liners. Subjects completed a trial on each of the tests under a handwear condition, had a 15-min rest break, and then moved on to the next handwear condition. During the break, subjects completed appropriate sections of the questionnaire.

This testing procedure was followed during all seven sessions. The pairs of subjects participating at the same hour had the same order of conditions, but the order was random across pairs of subjects and across sessions. All testing was conducted in a climatic chamber maintained at 12.8 ^{o}C with a relative humidity of 50% and a windspeed of 0.9 m/s.

Results

Dexterity Tests

Analysis of the data from the dexterity tests was carried out using SPSS/PC+, version 3.1 (SPSS Inc., 1988, 1989). Prior to analysis, a subject's time to complete a dexterity test under each combination of butyl gloves and glove liners at each session was transformed and expressed as a percentage of bare-hand time on the test at that session. The formula applied to the raw data was: (Gloves/Bare Hands) x 100. Thus, a score greater than 100% was obtained when test completion time with some combination of gloves and glove liners exceeded that with the bare hands. The percentage scores as a function of butyl glove thickness, liner type, and session were subsequently subjected to statistical analysis. Multivariate analyses of variance (MANOVAs) and univariate analyses of variance (ANOVAs) for repeated measures were performed on each dexterity test separately. The significance level was set at .05. The findings that are presented here are those for the univariate tests to which the Greenhouse-Geiser adjustment has been applied.

The results of the three-way, repeated measures ANOVA performed on the data for each dexterity test are summarized in Table 3. The ANOVAs for the three dexterity tests yielded similar findings. All interactions failed to achieve significance as did the main effect of glove liner. The only sources of variance that were significant were the main effects of butyl glove thickness and testing session.

Mean percentage scores on each dexterity test for the 0.36-mm and the 0.64-mm butyl gloves are presented in Figure 3. All the means are greater than 100% indicating that times to test completion were longer when the gloves were worn than when the hands were bare. It can also be seen in Figure 3 that the higher means on the tests are associated with the thicker butyl gloves. Thus, the significant main effect of glove thickness that was obtained in the analysis of each dexterity test reflects inferior performance with the 0.64-mm gloves in contrast to performance with the 0.36-mm butyl gloves.

Although the analysis of each dexterity test yielded a significant main effect of butyl glove thickness, the difference between the mean percentage scores for the two gloves varied among the tests (Figure 3). The smallest difference was on the O'Connor Finger Dexterity Test and the largest difference was on the Purdue Pegboard Assembly Test. However, the differences between bare-hand and gloved-hand performance levels were also smallest on the O'Connor Finger Dexterity Test and largest on the Purdue Assembly Test (Figure 3).

Table 3. Summary of Analyses of Variance Performed on the Dexterity Test Data

Factor	*df*[a]	*F* ratio	*p*[b]
	Cord and Cylinder Manipulation		
Glove	1, 11	37.86	.001
Liner	1, 11	<1.00	NS
Session	3.83, 42.17	13.37	.001
Glove x Liner	1, 11	<1.00	NS
Glove x Session	3.04, 33.44	1.26	NS
Liner x Session	3.24, 35.63	1.35	NS
Glove x Liner x Session	3.60, 39.64	1.88	NS
	O'Connor Finger Dexterity		
Glove	1, 11	6.86	.025
Liner	1, 11	1.04	NS
Session	3.67, 40.39	3.71	.05
Glove x Liner	1, 11	1.37	NS
Glove x Session	3.35, 36.81	1.06	NS
Liner x Session	3.49, 38.40	1.12	NS
Glove x Liner x Session	3.05, 33.54	1.37	NS
	Purdue Pegboard Assembly		
Glove	1, 11	8.94	.025
Liner	1, 11	1.13	NS
Session	3.74, 41.12	12.43	.001
Glove x Liner	1, 11	4.18	NS
Glove x Session	1.98, 21.75	<1.00	NS
Liner x Session	2.58, 28.34	1.38	NS
Glove x Liner x Session	3.30, 36.33	<1.00	NS

[a]The degrees of freedom reflect the Greenhouse-Geiser adjustment. [b]NS = Not significant.

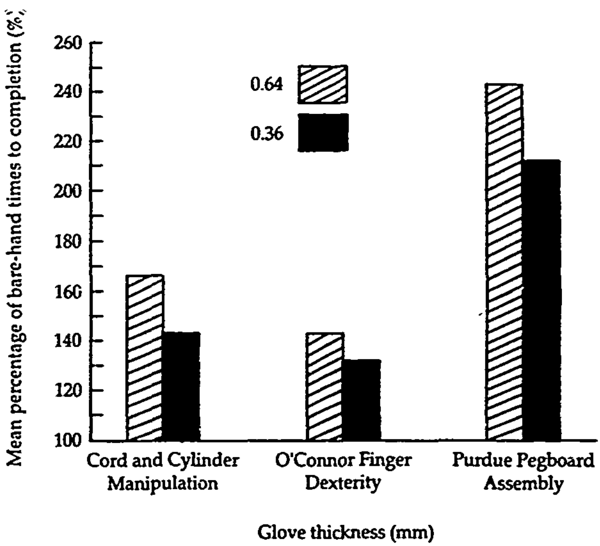

Figure 3. Mean dexterity test scores for each thickness of butyl gloves.

The significant main effect of session, which was obtained in the analysis of each dexterity test, is attributable to greater improvements in gloved-hand performance than in bare-hand performance as testing progressed. This can be seen in Figures 4 through 6, which are presentations of data from the Cord and Cylinder Manipulation, the O'Connor Finger Dexterity, and the Purdue Pegboard Assembly Tests, respectively. The figures contain the mean percentage scores for each session under each combination of butyl gloves and liners and they indicate that, across sessions, times to test completion decreased in each butyl glove and glove liner combination relative to bare-hand times.

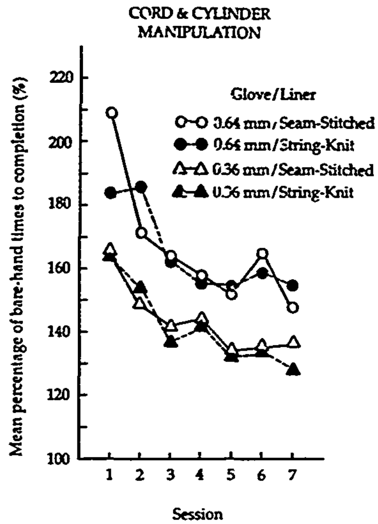

Figure 4. Mean Cord and Cylinder Manipulation Test scores for each session and each glove and liner combination.

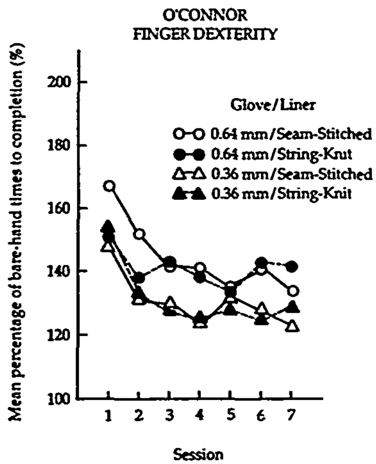

Figure 5. Mean O'Connor Finger Dexterity Test scores for each session and each glove and liner combination.

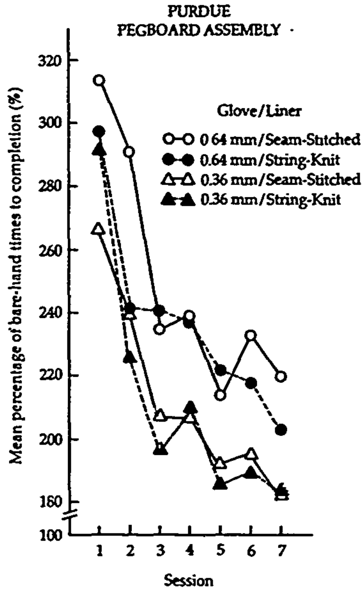

Figure 6. Mean Purdue Pegboard Assembly Test scores for each session and each glove and liner combination.

Comparison of the mean percentage scores in Figures 4 through 6 for the seam-stitched and the string-knit liners at each butyl glove thickness indicates that the two types of liners resulted in highly similar performance. This is as would be expected in light of the fact that the ANOVAs did not yield a significant liner effect (Table 3). On the Cord and Cylinder Manipulation and the O'Connor Finger Dexterity Tests, the means for the two types of liners, calculated over butyl glove thickness and session, differed by less than three percentage points. The difference between the means for the liners was somewhat greater on the Purdue Pegboard Assembly Test; the mean for the seam-stitched was 231% and the mean for the string-knit was 225%.

Although none of the interactions were found to be significant in the ANOVAs performed on the three dexterity tests, one interaction did approach significance ($p<.10$) on the Purdue Pegboard Assembly Test. It is the interaction between butyl glove thickness and liner type. This finding appears to be attributable to the fact that, when worn with the 0.36-mm gloves, the means for the two liners differed by one percentage point and, when worn with the 0.64-mm gloves, there was a difference of 12 percentage points between the liner means; the mean percentage score for the seam-stitched liner was 249% and the mean for the string-knit was 237%.

Questionnaire

Friedman analyses of variance by ranks (F_r) and chi-square (X^2) tests were carried out on portions of the questionnaire data to determine whether or not there were significant differences in the subjects' responses to the various butyl gloves and glove liners tested. For these analyses, SPSS/PC+, version 3.1 (SPSS Inc., 1988, 1989) was used. The significance level was set at .05.

Table 4 contains the median ratings, calculated across subjects and testing sessions, of the extent to which performance on each dexterity test was impaired by the butyl glove and glove liner combinations. Subjects rated the extent of impairment on a five-point scale from 1 (not at all impaired) through 5 (extremely impaired). On the O'Connor Finger Dexterity Test, the median rating for the 0.64-mm butyl gloves worn with the string-knit liners is in the moderately impaired range. The median on the Purdue Pegboard Assembly Test for the 0.64-mm gloves worn with the seam-stitched liners is also in the moderately impaired range. The remaining medians reflect ratings of between slight and moderate impairment. A separate Friedman analysis was performed on the data for each dexterity test, and none of the analyses revealed significant differences among the ratings given to the four butyl glove and glove liner combinations (Table 4).

In those instances in which a subject responded that dexterity was at least slightly impaired by the handwear being worn, he was to select from lists provided all the design characteristics and problem areas associated with a particular butyl glove and liner combination that contributed toward the impaired performance. Across all 12 subjects and seven testing sessions, a particular characteristic or problem area could be ascribed to a glove and liner combination as many as 84 times. Table 5 is a listing of the number and the percentage of times that a characteristic or a problem area was actually selected.

Table 4. Median Ratings by the Subjects (N = 12) Across Seven Sessions of the Extent to Which Each Glove and Liner Combination Impaired Performance on the Dexterity Tests

	Glove and Liner Combination				
	0.64-mm Butyl		0.36-mm Butyl		
Test	Seam-Stitch.	String-Knit	Seam-Stitch.	String-Knit	F_r[a]
Cord and Cylinder Manipulation	2.50	2.66	2.10	2.25	3.39
O'Connor Finger Dexterity	2.94	3.00	2.78	2.66	4.47
Purdue Pegboard Assembly	3.33	2.83	2.79	2.70	3.89

Note. Subjects rated the extent to which each glove and liner combination impaired performance according to the following scale: 1 = not at all; 2 = slightly; 3 = moderately; 4 = considerably; 5 = extremely.

[a]df = 3

It can be seen in Table 5 that finger length and bulk are among the design characteristics selected most frequently as impairing dexterity, regardless of the particular handwear combination being worn. There are relatively large differences between the thicknesses of butyl gloves in the percentages of time that three design characteristics were chosen. These are thickness, flexibility, and bulk. Each of these was selected more frequently as a factor that impaired performance when the 0.64-mm gloves were being used than when the thinner gloves were being worn. Differences in the frequencies of responses as a function of glove liner are not as apparent as the differences as a function of butyl glove thickness are. However, there was a tendency for the subjects to select one characteristic, slipperiness, more frequently when the seam-stitched liners were being worn than when the string-knit liners were being used (Table 5).

With regard to the problem areas indicated by the subjects, bulk and impaired feel were selected most frequently, regardless of the glove and liner combination being used (Table 5). The

Table 5. Number and Percentage of Times Across Seven Sessions That Each Design Characteristic and Problem Area Was Selected by the Subjects (N = 12) as Impairing Dexterity Performance

	Glove and Liner Combination							
	0.64-mm Butyl				0.36-mm Butyl			
	Seam-Stitch.		String-Knit		Seam-Stitch.		String-Knit	
Factor	n	%	n	%	n	%	n	%
Design Characteristics								
Bulk	64	76.19	67	79.76	49	58.33	51	60.71
Thickness	62	73.80	65	77.38	34	40.48	34	40.48
Finger Length	43	51.19	43	51.19	48	57.14	44	52.38
Flexibility	19	22.62	21	25.00	7	8.33	3	3.57
Slipperiness	16	19.04	11	13.09	20	23.80	14	16.66
Other	3	3.57	0	0.00	4	4.76	0	0.00
Problem Areas								
Impaired Feel	73	86.90	72	85.71	61	72.62	56	66.66
Bulky	56	66.66	62	73.80	42	50.00	47	55.95
Bunching Up	35	41.66	29	34.52	39	46.42	36	42.86
Stiff	18	21.42	18	21.42	3	3.57	3	3.57
Loose	16	19.05	10	11.90	24	28.57	12	14.28
Snagging	15	17.86	18	21.42	24	28.57	21	25.00
Slipping	14	16.66	11	13.09	21	25.00	12	14.28
Clingy	7	8.33	6	7.14	4	4.76	5	5.95
Pinching	6	7.14	7	8.33	10	11.90	7	8.33
Heavy	6	7.14	6	7.14	1	1.19	0	0.00
Rough	3	3.57	5	5.95	0	0.00	0	0.00
Rubbing	1	1.19	0	0.00	1	1.19	1	1.19
Hot	1	1.19	0	0.00	0	0.00	0	0.00
Tight	1	1.19	1	1.19	1	1.19	2	2.38
Pressure	0	0.00	0	0.00	0	0.00	0	0.00
Sweaty	0	0.00	1	1.19	0	0.00	1	1.19
Scratchy	0	0.00	0	0.00	0	0.00	0	0.00
Other	0	0.00	0	0.00	0	0.00	0	0.00

subjects ascribed the problem areas of bulk, impaired feel, and stiffness more often to the 0.64-mm than to the 0.36-mm gloves. In addition, although the factors of roughness and heaviness were only infrequently chosen, they were associated almost solely with the 0.64-mm gloves. With the possible exceptions of slipping and

looseness, which were more frequently associated with the seam-stitched than with the string-knit liners, there were no consistent differences between the liners in the problem areas selected.

At the end of a session, the subjects ranked the four glove and glove liner combinations, giving a rank of 1 to the combination that had most impaired their performance during the session and a rank of 4 to the combination that had least impaired their performance. Medians calculated across subjects and sessions revealed that the 0.64-mm gloves used with the string-knit liners was the combination chosen as resulting in the greatest dexterity impairment (Mdn = 1.36), followed by the 0.64-mm used with the seam-stitched liners (Mdn = 2.10). Of the remaining two combinations, the 0.36-mm gloves with the seam-stitched liners had a median rating of 2.93 and the highest median, 3.50, was for the 0.36-mm gloves with the string-knit liners. The Friedman analysis revealed significant differences among the glove and liner combinations, $\underline{F}_r(3, N = 12) = 11.87$, $\underline{p}<.01$. Post-hoc Friedman procedures (Siegel and Castellan, 1988) revealed that the only two handwear combinations that differed significantly from each other were those with the lowest and with the highest medians. That is, the 0.64-mm butyl gloves with the string-knit liners and the 0.36-mm gloves with the string-knit liners.

At the end of the last testing session, subjects were asked to select the best and the worst combination of butyl gloves and glove liners with regard to performance on each of the three dexterity tests. Their votes, which are presented in Table 6, do not indicate a consistent preference for, or dislike of, a particular glove and liner combination over all tests. However, there was a tendency for the 0.36-mm gloves with string knit liners to be chosen most often as the best combination and for the 0.64-mm gloves with the string-knit liners to be selected most often as the worst combination.

The data on the best and the worst glove combinations were collapsed to determine the number of men selecting each of the two thicknesses of butyl gloves, and each of the two types of liners, as the better and as the worse for performance on each dexterity test. These tallies, which are presented in Table 6, were analyzed using $\underline{X}^2$ goodness of fit tests to determine whether or not one of the glove thicknesses, or one of the liners, was selected more frequently than the other as being the better or the worse to use on a particular dexterity test. Although more subjects selected the 0.36-mm gloves as being the better and the 0.64-mm as being the worse of the butyl gloves, the $\underline{X}^2$ tests did not reveal a significant difference between the gloves in terms of the number of subjects who selected one

Table 6. Votes by the Subjects (N = 12) for the Best and the Worst Glove and Liner Combinations on Each Dexterity Test

	Glove and Liner Combination							
	0.64-mm		0.36-mm		Glove		Liner	
	Seam-Stitch.	Str.-Knit	Seam-Stitch.	Str.-Knit	0.64-mm	0.36-mm	Seam-Stitch.	Str.-Knit
	Cord and Cylinder Manipulation							
Best	2	2	3	5	4	8	5	7
Worst	1	8	2	1	9	3	3	9
	O'Connor Finger Dexterity							
Best	2	1	2	7	3	9	4	8
Worst	1	5	2	1	9	3	6	6
	Purdue Pegboard Assembly							
Best	0	3	3	6	3	9	3	9
Worst	3	4	4	1	7	5	7	5

over the other, $X^2(1, N = 12) \leq 3.00$, $p>.05$. The analyses performed on the selections of the better and the worse liners for each test also failed to yield significant differences between the two liners, $X^2(1, N = 12) \leq 3.00$, $p>.05$.

The final question posed at the last testing session required that the subjects indicate which of the two butyl gloves and which of the two glove liners they had preferred wearing over the course of their participation in the study. The subjects were also asked to provide reasons for their choices. Ten of the 12 subjects selected the 0.36-mm gloves, a number significantly different from chance, $X^2(1, N = 12) = 5.33$, $p<.05$. The reasons given for preferring the thinner gloves are that they were more flexible than the 0.64-mm and that it was easier to sense the shape of objects through them.

With regard to the preferred liner, eight of the 12 subjects selected the string-knit. The number of subjects opting for the string-knit versus the number preferring the seam-stitched liner did not differ significantly from chance, $\chi^2(1, N = 12) = 1.33$, $p > .05$. The reasons given for preferring the string-knit version include greater comfort, a tighter fit, and less slipperiness. The reasons given for preferring the seam-stitched liner are better tactility and greater comfort because it did not bunch up.

Discussion

As in Bensel's (1980, 1990) earlier studies of chemical protective handwear, it was found in this investigation that the Army's butyl gloves impair manual performance relative to bare-hand performance. The finding from Bensel's (1980, 1990) previous work that substantial benefits can be derived from practicing manual tasks while wearing the protective gloves was also confirmed. Over the seven testing sessions, the subjects' times to complete each of three dexterity tests with gloved hands improved significantly relative to times with the bare hands.

Again with regard to practice, it is notable that the analyses performed on the results of the three dexterity tests did not yield significant interactions between the glove and the session variables. Thus, performance changes over sessions with two thicknesses of butyl gloves, 0.64 mm and 0.36 mm, were essentially parallel. In addition, a significant main effect of butyl glove was obtained in the analysis of each dexterity test, with faster times to test completion being associated with the thinner gloves. Therefore, as Bensel (1990) found, reduction of the burden that chemical protective gloves impose on a user's manual capabilities can be achieved by wearing the 0.36-mm, as opposed to the 0.64-mm, butyl gloves.

The issues of particular interest in this study were related to the liners worn under the chemical protective gloves. In the investigation conducted by Branson et al. (1988), the subjects wore the glove liners with the 0.36-mm butyl gloves, and there were no significant differences between the seam-stitched and the string-knit liners in their effects on dexterity performance. The 0.64-mm butyl gloves, as well as the 0.36-mm gloves, were included in this study in order to determine whether or not the two types of liners would differentially affect manual performance when worn with the thicker butyl gloves.

The analyses of the subjects' times to complete the three dexterity tests did not yield significant interactions between the glove and the liner variables. However, the interaction did approach significance on one of the dexterity tests, the Purdue Pegboard Assembly Test. On this test, performance levels with the two types of liners were essentially equal when the liners were worn with the 0.36-mm gloves. When the liners were worn with the thicker butyl gloves, performance with the string-knit was somewhat better than performance with the seam-stitched version.

The reason that the interaction between the glove and the liner variables approached significance on one, but not all, of

the dexterity tests is not clear. The three dexterity tests used in this study required fine-finger manipulations, and the Cord and Cylinder Manipulation Test, like the Purdue Pegboard Assembly Test, involved use of both hands. There was, however, a greater difference between bare-hand and gloved-hand performance levels on the Purdue Pegboard Assembly Test than on the other two dexterity tests, regardless of the particular butyl gloves and liners being worn. Therefore, it is possible that the Purdue Pegboard Assembly Test was more sensitive to handwear effects than the Cord and Cylinder Manipulation and the O'Connor Finger Dexterity Tests were.

In the investigation of glove liners conducted by Branson et al. (1988), the subjects used butyl gloves and an overgarment coat, but they did not wear the other components of the Army's chemical protective attire. In this study, the subjects wore the Army's complete ensemble, including overgarment trousers, overboots, and a full-face mask, because of the possibility that the burden of working in the protective handwear would combine with the burden of working in the other articles of protective attire, most particularly the mask, to yield differences in dexterity performance between the liners. The analyses of the performance data indicated that times to completion of the three dexterity tests did not differ significantly as a function of whether the seam-stitched or the string-knit glove liners were worn. On the basis of these findings, it would appear that the manual performance of soldiers, even those who are outfitted in the complete chemical protective ensemble, will not be helped or hindered by use of one of these liners rather than the other. However, the fact that the interaction between the glove and the liner variables approached significance on the Purdue Pegboard Assembly Test suggests that there may be advantages to using the string-knit, rather than the seam-stitched, liners under certain circumstances, such as execution of particularly difficult manual tasks while wearing the 0.64-mm gloves and the other components of the Army's chemical protective ensemble.

As was the case with the performance times on the dexterity tests, there was no strong evidence from the subjects' responses on the questionnaire that one glove liner was consistently better than the other. Contrasts among the glove and liner combinations with regard to the extent that they impaired performance on each dexterity test failed to yield any significant difference in the subjects' ratings. It is interesting to note, though, that the highest impairment ratings across all glove and liner combinations and dexterity tests were given to the 0.64-mm butyl glove and seam-stitched liner combination on the Purdue Pegboard Assembly Test. This may be an indication that the subjects experienced more difficulties completing the Purdue Pegboard Assembly Test while wearing handwear than they did completing the

other dexterity tests and that they found the Purdue Test to be particularly onerous when using the 0.64-mm gloves and the seam-stitched liners.

The specific design characteristics and problem areas that the subjects cited as impairing their dexterity performance reflected differences between the two thicknesses of butyl gloves rather than differences between the two types of glove liners. For example, thickness, bulk, flexibility, and impaired feel were factors ascribed more frequently to the thicker butyl gloves than to the thinner.

The frequency with which subjects cited handwear characteristics and problem areas varied little as a function of glove liner. There was a tendency, however, for the factors of slipperiness and looseness to be associated somewhat more often with the seam-stitched than with the string-knit liners. Branson et al. (1988) found that the subjects in their study rated the two liners differently for the descriptor "snug," with the seam-stitched being given ratings indicating that they were snugger than the string-knit. To the extent that the term "loose" describes a characteristic that is the opposite of snug, the subjects in this study seemed to find the string-knit, rather than the seam-stitched, to be the snugger of the two types of liners.

The subjects in the Branson et al. (1988) study also differentiated between the two liners on the basis of the ratings given the descriptor "heavy," and the string-knit were rated higher in this regard than the seam-stitched liners. There was no indication in this study that the subjects differentiated between the two types of liners on the basis of heaviness. However, the subjects in this study, unlike those in the study by Branson et al. (1988), were exposed repeatedly to the liners over seven working days and had the opportunity to wear the liners with two thicknesses of butyl gloves. Given their different experiences, the subjects in the two studies may well have developed different opinions of the liners.

On the other questions posed regarding the handwear, the subjects in this study also failed to indicate a strong and consistent preference for one of the two glove liners. When asked to rank the four glove and liner combinations in terms of impairment in dexterity performance, the medians indicated that the subjects found both the highest and the lowest levels of impairment to be associated with the string-knit liners. In the subjects' opinions, the greatest impairment was experienced when these liners were worn with the 0.64-mm gloves and the least impairment was experienced when these liners were worn with the 0.36-mm gloves. Furthermore, in selecting the best and the worst

glove and liner combinations for use on each dexterity test, the subjects again did not consistently select one liner over another.

When asked specifically to select the gloves and the liners that they preferred, 10 of the 12 subjects chose the 0.36-mm gloves and eight of the 12 chose the string-knit version of the liners. Thus, the subjects showed a stronger preference for the thinner of the two butyl gloves than they did for either version of the liners.

From the perspectives of both efficiency of manual manipulations and users' opinions, there is no basis in the findings from this study for concluding that the string-knit liners represent an improvement relative to the seam-stitched. With the exception of a trend toward better dexterity performance with the string-knit version on one of the three dexterity tests, and then only when the string-knit were worn with the thicker of the two butyl gloves, the liners were essentially equal in terms of the manual capabilities that they afforded. In addition, when forced to indicate which of the two type of liners they preferred, only two more subjects of the 12 selected the string-knit than selected the seam-stitched. The findings from the study by Branson et al. (1988) also failed to differentiate between the liners with regard to the parameters of sweat rate, hand skin temperature, and perceived hand temperature. It is possible that the liners differ in durability. However, because of the short periods of wear, relative durability of the liners was not addressed in this study or in the study by Branson et al.

Unlike the findings related to the glove liners, the findings from this study with regard to the butyl gloves did provide evidence that the 0.36-mm gloves result in more efficient performance than the 0.64-mm gloves do. The subjects also preferred the thinner handwear. Thus, insofar as the butyl gloves are concerned, their difference in thickness of 0.18 mm significantly affected dexterity capabilities and subjects' opinions. The difference of 0.04 mm in the thicknesses of the glove liners was not obvious in terms of dexterity effects or the preferences of the subjects. A question for further study is whether larger differences in the thicknesses of glove liners have a significant effect on manual performance, and on subjects' preferences. With such information, it may be possible to identify glove liners that represent a substantial improvement over the seam-stitched version used by soldiers today.

Conclusions

Thickness of the butyl gloves under which the liners were worn proved to be a potent variable that affected manual performance and subjects' opinions. However, there were no substantial differences between the seam-stitched and the string-knit liners with regard to the dexterity capabilities that they afforded or the subjects' preferences. Thus, there is no basis on which to suggest that the seam-stitched liners, which are those used presently by soldiers, should be replaced by the string-knit. There is, however, reason to recommend use of the 0.36-mm butyl gloves whenever their use is compatible with the primary requirement of protecting the skin from exposure to toxic chemicals.

This document reports research undertaken at the US Army Natick Research, Development and Engineering Center and has been assigned No. NATICK/TR-91/002 in the series of reports approved for publication.

References

Bensel, C. K. (1980). A human factors evaluation of two types of rubber CB protective gloves (Tech. Rep. NATICK/TR-80/005). Natick, MA: U.S. Army Natick Research and Development Command. (AD A084 716)

Bensel, C. K. (1990). The effects of various thicknesses of chemical protective gloves on manual dexterity. Manuscript in preparation.

Bensel, C. K., Teixeira, R. A., and Kaplan, D. B. (1987). The effects of U.S. Army chemical protective clothing on speech intelligibility, visual field, body mobility and psychomotor coordination of men (Tech. Rep. NATICK/TR-87/037). Natick, MA: U.S. Army Natick Research, Development and Engineering Center. (AD A188 478)

Branson, D. H., Abusamra, L., Hoener, C., and Rice, S. (1988). Effects of glove liners on sweat rate, comfort, and psychomotor task performance. Textile Research Journal, 58, 166-173.

Cattroll, S. W. (1983). Dexterity comparison between Canadian and French CW gloves (Tech. Note 82-36). Ottawa, Canada: Defence Research Establishment.

Churchill, E., McConville, J. T., Laubach, L. L., and White, R. M. (1971). Anthropometry of U.S. Army aviators - 1970 (Tech. Rep. 72-52-CE). Natick, MA: U.S. Army Natick Laboratories. (AD 743 528)

Clauser, C., Tebbetts, I., Bradtmiller, B., McConville, J., and Gordon, C. C. (1988). Measurer's handbook: U.S. Army anthropometric survey, 1987-1988 (Tech. Rep. NATICK/TR-88/043). Natick, MA: U.S. Army Natick Research, Development and Engineering Center. (AD A202 721)

Cox, T. J. and Jeffers, A. R. (1981). Ground crew chemical defense equipment task-time degradation test (Tech. Rep. ASD-TR-81-5003). Wright-Patterson Air Force Base, OH: Aeronautical Systems Division.

Department of the Army. (1977). Nuclear, biological and chemical defense (Field Manual FM 21-40). Washington, DC: Department of the Army, Headquarters.

Department of the Army. (1986). Gloves and glove set, chemical protective (Military Specification MIL-G-43976B). Natick, MA: U.S. Army Natick Research, Development and Engineering Center.

Department of the Army. (1987). Gloves, cloth, cotton, knitted, lightweight (Military Specification MIL-G-3866G). Natick, MA: U.S. Army Natick Research, Development and Engineering Center.

Fleishman, E. A. (1954). Dimensional analysis of psychomotor abilities. Journal of Experimental Psychology, 48, 437-454.

Goldman, R. F. (1970, June). Tactical implications of the physiological stress imposed by chemical protective clothing systems. Paper presented at the 1970 Army Science Conference, West Point, NY.

Hines, M. and O'Connor, J. (1926). A measure of finger dexterity. Journal of Personnel Research, 4, 379-382.

Lee, R. A., Glumm, M., and Singapore, M. (1983). Evaluation of combat vehicle gunner performance with various combinations of NBC protective apparel: a laboratory study (Tech. Rep. 12714). Warren, MI: U.S. Army Tank-Automotive Command.

McGinnis, J. M., Bensel, C. K., and Lockhart, J. M. (1973). Dexterity afforded by CB protective gloves (Tech. Rep. 73-35-PR). Natick, MA: U.S. Army Natick Laboratories. (AD 759 123)

McGinnis, J. M., Lockhart, J. M., and Bensel, C. K. (1972). A human factors evaluation of cold-wet handwear (Tech. Rep. 73-23-PR). Natick, MA: U.S. Army Natick Laboratories. (AD 756 417)

Siegel, S. and Castellan, N. J. (1988). Nonparametric statistics for the behavioral sciences. New York: McGraw-Hill.

SPSS, Inc. (1988). SPSS/PC+ V2.0 base manual for the IBM PC/XT/AT and PS/2. Chicago: Author.

SPSS, Inc. (1989). SPSS/PC+ update for V3.0 and V3.1 for the IBM PC/XT/AT and PS/2. Chicago: Author.

Stack, G. B. and Sager, H. W. (1988). Troop performance degradation in Mission Oriented Protective Posture Level 4. communication operations (Tech. Rep. DPG-FR-88-701). Dugway, UT: U.S. Army Dugway Proving Ground.

Tiffin, J. (1979). Purdue pegboard examiner manual. Lafayette, IN: Lafayette Instrument Company.

Tilley, R. I., Standerwick, J. M., and Long, G. J. (1987). Ability of the wet bulb globe temperature index to predict heat stress in men wearing NBC protective clothing. Military Medicine, 152, 554-556.

Waugh, J. D. and Kilduff, P. W. (1984). Missile component repair while wearing NBC protective clothing (Tech. Memorandum 1-84). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

White, R. M. and Churchill, E. (1971). The body size of soldiers: U.S. Army anthropometry - 1966 (Tech. Rep. 72-51-CE). Natick, MA: U.S. Army Natick Laboratories. (AD 743 465)

Appendix A

Hand Measurement Techniques

Appendix A. Hand Measurement Techniques

The techniques used to obtain the hand dimensions of the subjects in this study were based upon those employed by White and Churchill (1971) in their 1966 anthropometric survey of U.S. Army men, by Churchill, McConville, Laubach, and White (1971) in their 1970 survey of U.S. Army male aviators, and by Clauser, Tebbetts, Bradtmiller, McConville, and Gordon (1988) in the 1987-1988 survey of U.S. Army men and women. The equipment consisted of a 2-meter steel tape (K&E Tip-Top Wyteface) and a sliding caliper (Gneupel). The hand measurements taken and the techniques employed are presented below.

Hand Length

The subject sits, with his right hand and fingers extended, palm up, and resting on a flat surface. With the bar of the sliding caliper parallel to the long axis of the hand, measure the distance from the wrist crease to the tip of the middle finger.

Palm Length

The subject sits, with his right hand and fingers extended, palm up, and resting on a flat surface. With the sliding caliper, measure the distance from the wrist crease to the skin crease at the base of the middle finger. The measure is taken parallel to the long axis of the hand.

Thumb Crotch Height

The subject sits, with his right hand and fingers extended, palm up, and with his thumb extended away from his hand. The length of the thumb crotch is measured from the skinfold at the base of the thumb to the notch between the first and second fingers. A sliding caliper is used.

Hand Circumference

The subject's right hand is extended, palm down, and the thumb is held away from the fingers. The circumference of the right hand is measured with a steel tape passing over the metacarpal-phalangeal joints of the index and little fingers.

Wrist Circumference

The subject's right hand is extended, palm up. The minimum circumference of the wrist is measured, parallel to the long axis of the forearm, at the level of the wrist using a steel tape.

Appendix B

Hand Dimensions and Glove Sizes of the Subjects

Appendix B. Hand Dimensions (in cm) and Glove Sizes[a] of the Subjects

	Hand Dimension					Glove Size		
Subj.	Hand Lgth.	Palm Lgth.	Thumb Crotch Ht.	Hand Circ.	Wrist Circ.	0.64-mm/ 0.36-mm Butyl	Seam-Stitch. Liner	Str. Knit Liner
1	18.3	10.1	4.0	20.3	16.2	S	S	M
2	18.3	10.7	4.4	20.2	15.9	S	S	M
3	19.2	11.0	4.1	20.8	17.2	S	M	M
4	18.5	10.3	4.4	21.9	16.8	M	M	M
5	18.8	11.3	4.8	20.7	17.0	M	M	M
6	19.1	11.0	4.5	20.6	17.3	M	M	M
7	19.2	11.3	3.7	21.3	17.2	M	M	M
8	19.4	10.8	5.0	21.3	17.2	M	M	M
9	19.5	10.4	4.7	22.0	17.3	M	M	M
10	20.1	11.3	3.9	21.7	16.8	M	M	M
11	19.0	10.7	4.4	23.2	18.4	L	M	L
12	19.4	11.7	4.1	21.8	17.7	L	M	L

[a]S = small; M = medium; L = large.

Appendix C

Questionnaire for Dexterity Tests

Appendix C. Questionnaire For Dexterity Tests

Name:______________________________ Date:__________ Day:______

Handwear:__________________________

Section I.

For each task, indicate the extent to which the glove set that you just wore IMPAIRED your performance. Use the scale provided below, and circle one number for each task.

	NOT AT ALL	SLIGHTLY	MODERATELY	CONSIDERABLY	EXTREMELY
1. Cord and Cylinder	0	1	2	3	4
2. O'Connor	0	1	2	3	4
3. Pegboard Assembly	0	1	2	3	4

IF YOU SELECTED "Not at all" FOR ALL THREE TASKS, SKIP THE NEXT TWO SECTIONS (II AND III) OF THIS QUESTIONNAIRE.

Section II. DESIGN CHARACTERISTICS

Some design characteristics of gloves are listed below. Place an "X" next to ALL the characteristics of the gloves sets that contributed toward IMPAIRING your performance on the LAST set of trials.

_____Thickness

_____Flexibility

_____Finger lengths

_____Bulkiness

_____Slipperiness

_____Other. Specify______________________________

Section III. PROBLEMS

Some problems that you may experience while wearing gloves are listed below. Place an "X" next to ALL the problems with the glove sets that contributed toward IMPAIRING your performance on the LAST set of trials.

_______Bulky

_______Rubbing

_______Impaired feel

_______Bunching up

_______Pressure

_______Pinching

_______Slipping

_______Stiff

_______Loose

_______Hot

_______Tight

_______Snagging

_______Sweaty

_______Clingy

_______Rough

_______Heavy

_______Scratchy

_______Other. Specify________________________________

Section IV. END OF SESSION QUESTION

Rank the four glove sets from 1 through 4 with regard to the extent to which they impaired your performance on the manual tasks today. Give a rank of "1" to the glove set that <u>MOST IMPAIRED</u> your performance. (The rank of "4" would be given to the glove set that <u>LEAST IMPAIRED</u> your performance.) Use all numbers from 1 through 4.

______25 mil outer glove and cotton liner

______25 mil outer glove and string-knit liner

______14 mil outer glove and cotton liner

______14 mil outer glove and string-knit liner

Section V. END OF STUDY QUESTIONS

1. CORD AND CYLINDER STRINGING TEST

   a. Which glove set was the BEST for stringing the cylinders on this test?

      _____25 mil outer glove and cotton liner

      _____25 mil outer glove and string-knit liner

      _____14 mil outer glove and cotton liner

      _____14 mil outer glove and string-knit liner

   b. Which glove set was the WORST for stringing the cylinders on this test?

      _____25 mil outer glove and cotton liner

      _____25 mil outer glove and string-knit liner

      _____14 mil outer glove and cotton liner

      _____14 mil outer glove and string-knit liner

2. O'CONNOR FINGER DEXTERITY TEST

   a. Which glove set was the BEST for placing the small pins in the holes on this test?

      _____25 mil outer glove and cotton liner

      _____25 mil outer glove and string-knit liner

      _____14 mil outer glove and cotton liner

      _____14 mil outer glove and string-knit liner

   b. Which glove set was the WORST for placing the small pins in the holes on this test?

      _____25 mil outer glove and cotton liner

      _____25 mil outer glove and string-knit liner

      _____14 mil outer glove and cotton liner

      _____14 mil outer glove and string-knit liner

3. PURDUE PEGBOARD ASSEMBLY TEST

a. Which glove set was the BEST for building the assemblies of pins, collars, and washers?

_____25 mil outer glove and cotton liner

_____25 mil outer glove and string-knit liner

_____14 mil outer glove and cotton liner

_____14 mil outer glove and string-knit liner

b. Which glove set was the WORST for building the assemblies of pins, collars, and washers?

_____25 mil outer glove and cotton liner

_____25 mil outer glove and string-knit liner

_____14 mil outer glove and cotton liner

_____14 mil outer glove and string-knit liner

4. Put an "X" next to the liner that you preferred wearing during this study.

_____Cotton

_____String knit

Explain the reasons for your choice:____________________________

____

5. Put an "X" next to the butyl glove that you preferred wearing during this study.

_____25 mil

_____14 mil

Explain the reasons for your choice:____________________________

____